Critical revision of the article: JM, RV, ER, GC, CT
Final approval of the article: JM, RV, ER, GC, CT, JC, FA
Statistical analysis: JM, ER, CT
Obtained funding: Not applicable
Overall responsibility: JM

## REFERENCES

1. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL. Surgeon volume and operative mortality in the United States. N Engl J Med 2003;349:2117-27.
2. van Gijn W, Gooiker GA, Wouters MW, Post PN, Tollenaar RA, van de Velde CJ. Volume and outcome in colorectal cancer surgery. Eur J Surg Onc 2010;36 (Suppl 1):S55-63.
3. Park HS, Roman SA, Sosa JA. Outcomes from 3144 adrenalectomies in the United States: which matters more, surgeon volume or specialty? Arch Surg 2009;144:1060-7.
4. Eppsteiner RW, Csikesz NG, McPhee JT, Tseng JF, Shah SA. Surgeon volume impacts hospital mortality for pancreatic resection. Ann Surg 2009;249:635-40.
5. Nathan H, Cameron JL, Choti MA, Schulick RD, Pawlik TM. The volume-outcomes effect in hepato-pancreato-biliary surgery: hospital versus surgeon contributions and specificity of the relationship. J Am Coll Surg 2009;208:528-38.
6. Hannan EL, Radzyner M, Rubin D, Dougherty J, Brennan MF. The influence of hospital and surgeon volume on in-hospital mortality for colectomy, gastrectomy, and lung lobectomy in patients with cancer. Surgery 2002;131:6-15.
7. Dardik A, Lin JW, Gordon TA, Williams GM, Perler BA. Results of elective abdominal aortic aneurysm repair in the 1990s: a population-based analysis of 2335 cases. J Vasc Surg 1999;30:985-95.
8. Hannan EL, Popp AJ, Tranmer B, Fuestel P, Waldman J, Shah D. Relationship between provider volume and mortality for carotid endarterectomies in New York state. Stroke 1998;29:2292-7.
9. Cowan JA Jr, Dimick JB, Thompson BG, Stanley JC, Upchurch GR Jr. Surgeon volume as an indicator of outcomes after carotid endarterectomy: an effect independent of specialty practice and hospital volume. J Am Coll Surg 2002;195:814-21.
10. Dimick JB, Cowan JA Jr, Stanley JC, Henke PK, Pronovost PJ, Upchurch GR Jr. Surgeon specialty and provider volumes are related to outcome of intact abdominal aortic aneurysm repair in the United States. J Vasc Surg 2003;38:739-44.
11. Marlow NE, Barraclough B, Collier NA, Dickinson IC, Fawcett J, Graham JC, et al. Effect of hospital and surgeon volume on patient outcomes following treatment of abdominal aortic aneurysms: a systematic review. Eur J Vasc Endovasc Surg 2010;40:572-9.
12. Cho JS, Kim JY, Rhee RY, Gupta N, Marone LK, Dillavou ED, et al. Contemporary results of open repair of ruptured abdominal aortoiliac aneurysms: effect of surgeon volume on mortality. J Vasc Surg 2008; 48:10-7.
13. McPhee JT, Robinson WP III, Eslami MH, Arous EJ, Messina LM, Schanzer A. Surgeon case volume, not institution case volume, is the primary determinant of in-hospital mortality after elective open abdominal aortic aneurysm repair. J Vasc Surg 2011;53:591-9.
14. Healthcare Cost and Utilization Project. Overview of the National Inpatient Sample of the Healthcare Cost and Utilization Project. Available at: http://www.hcup-us.ahrq.gov/nisoverview.jsp. Accessed September 1, 2010.
15. Modrall JG, Rosero EB, Smith ST, Arko FR III, Valentine RJ, Clagett GP, et al. Operative mortality for renal artery bypass in the United States: results from the National Inpatient Sample. J Vasc Surg 2008; 48:317-22.
16. Modrall JG, Rosero EB, Smith ST, Arko FA III, Valentine RJ, Clagett GP, et al. Effect of hospital volume on in-hospital mortality for renal artery bypass. Vasc Endovasc Surg 2009;43:339-45.
17. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. J Clin Epidemiol 1992;45:613-9.
18. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373-83.
19. Hobson RW 2nd, Howard VJ, Roubin GS, Ferguson RD, Brott TG, Howard G, et al. Credentialing of surgeons as interventionalists for carotid artery stenting: experience from the lead-in phase of CREST. J Vasc Surg 2004;40:952-7.
20. Shahian DM, Silverstein T, Lovett AF, Wolf RE, Normand SL. Comparison of clinical and administrative data sources for hospital coronary artery bypass graft surgery report cards. Circulation 2007; 115:1518-28.
21. Iezzoni LI, Foley SM, Daley J, Hughes J, Fisher ES, Heeren T. Comorbidities, complications, and coding bias. Does the number of diagnosis codes matter in predicting in-hospital mortality? JAMA 1992; 267:2197-203.

Submitted Mar 19, 2011; accepted May 17, 2011.

## INVITED COMMENTARY

**Timothy F. Kresowik, MD,** *Iowa City, Iowa*

There have been numerous publications on the relationship between volume and outcome for various complex surgical procedures. The concept that more experience leads to better outcomes certainly has face validity. What has been more problematic is how to quantify this relationship in a way that could be and/or should be used to guide credentialing or certification. Although most publications do show a statistically significant positive relationship between volume of procedures performed and better outcomes, the linear correlation is weak. Setting arbitrary minimum thresholds is potentially associated with a perverse incentive to try to meet the target number by doing more unnecessary procedures.

In addition, the finding of a statistically significant difference does not mean the difference is clinically significant. For example, if the mortality rate for surgeons with a volume of less than five cases per year was 6% and the mortality rate was 5% for surgeons who do more than 30 cases per year, most of us would not consider the 1% difference in mortality enough to justify a credentialing threshold.

The report by Modrall et al has similar findings and limitations as most of the other publications about the procedure volume outcome relationship. Although clearly at the extremes of low and high volumes there is a significant difference in mortality for open abdominal aortic aneurysm (AAA) repair, they did not demonstrate a clear stepwise decrement in mortality with either increasing AAA or composite volume (Figs 1 and 2). Their individual case volumes are also strikingly low with the finding that more than 50% of the surgeons in the database did one or less open AAA repairs per year and one or less "composite" open vascular procedures per year. This finding may be more indicative of the considerable limitations of the NIS database because of the 20% sampling strategy and the fact that one-third of the cases could not be associated with an individual surgeon than a representative of the real world of vascular procedures.

Nonetheless, the important "take-home" message of this report is the finding that composite vascular volume is a better predictor of better outcomes than open AAA repair volume alone. One would think that the aforementioned limitations of the database would not invalidate this finding. I would agree with the authors' conclusion that this suggests that overall experience with related types of procedures may be a better criteria for credentialing than a procedure-specific focus.